

# Emerging Technologies for Bioethanol Recovery Using Membrane Processes

Travis C. Bowen, Vasudevan V. Namboodiri, and Leland M. Vane

U.S. Environmental Protection Agency, ORD/NRMRL/STD/CPB, Cincinnati, OH, USA

The U.S. EPA National Risk Management Research Laboratory (NRMRL) Pervaporation Team is actively involved in developing various Green Technologies:

- Energy efficient separation processes
- Biofuel production
- Nano technology

**Objective:** Biofuel production from waste biomass

- Fermentation
- Biofuel recovery
- Novel polymer and nano-composite membranes

→ Move toward distributed small-scale ethanol production that is **economical and sustainable**

- waste biomass available throughout rural U.S.

## Background:

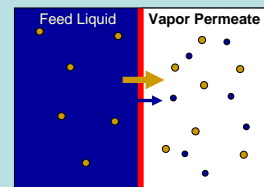
Fermentation – converts biomass to ethanol or other biofuels

- Biomass includes agricultural wastes, cheese whey, winery wastes, pulp and paper sludge, and many other sources

Pervaporation – membrane process

- Transport by adsorption and diffusion
- **Potentially more energy efficient** than traditional separation methods such as distillation
- **Cost effective** for small- and medium-scale applications

Pervaporation = **Per**meation + **Evap**oration



Non-porous or molecularly porous membrane (selective for Species 1)

## Fermentation and Separation Process Integration:

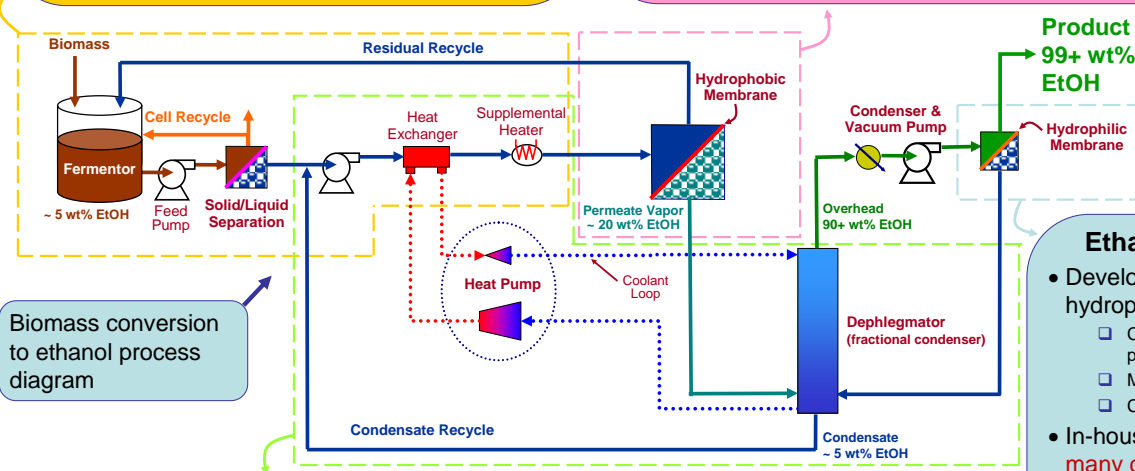
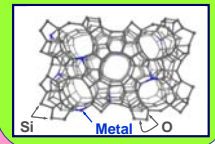
- Optimization of Fermentation parameters
  - Selection and amount of enzyme
  - Temperature & fermentation time
- Removal of cells and other solids
  - Microfiltration or centrifugation
- Tuning of Biofuel recovery and purification
  - Development and selection of separation processes - pervaporation, vapor separation etc.
- Recycling aspects

## Ethanol Removal:

- Ethanol-selective membrane development
  - Polymer or in-house zeolite nanoparticle/polymer mixed-matrix membranes
- Membrane evaluation
  - In-house membranes
  - Membranes developed by other organizations - CeraMem Corp.
- Membrane performance & stability
  - Effect of fermentation byproducts
  - Long-term pervaporation measurements
  - Adsorption characterization of membrane materials

**Zeolite** – nanoporous crystal

Atomic stick diagram of MFI structure zeolite



Biomass conversion to ethanol process diagram



Silicalite-1 zeolite membrane being developed by CeraMem Corp.

## Ethanol Dehydration:

- Developing high-performance hydrophilic membranes
  - Cross-linked blend of polyalcohols and polyamines
  - Mixed-matrix membranes
  - Comparison of commercial technologies
- In-house membranes **outperform many commercially available membranes**
  - Novel & Inexpensive
  - US patent applications filed – one recently awarded

## Energy Recovery:

- Fractional condenser **improves separation without requiring additional energy**
  - Must condense to recover product
- Heat integration **reduces operating costs**

## Collaborations:

Membrane Technology and Research, Inc. (MTR), CeraMem Corp., Kraft Foods, Integrated Separation Solutions, PFM Corp., BC International, University of Florida – Prof. Lonnie Ingram, Troy Boiler Works

Want to learn more?

Travis Bowen, Ph.D.  
US EPA, 26 W. Martin Luther King Dr.  
M/S443, Cincinnati, OH 45268 USA  
FAX: (513) 569-7677  
Ph: (513) 569-7718  
e-mail: bowen.travis@epa.gov  
Vasudevan Namboodiri, Ph.D.  
Same address and fax  
Ph: (513) 487-2700  
e-mail: namboodiri.vasu@epa.gov



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